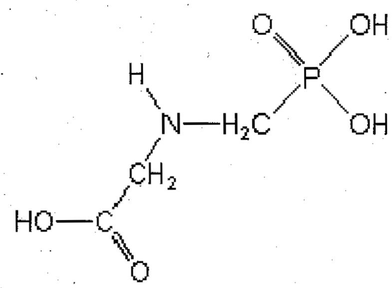
United States Environmental Protection Agency

Office of Prevention, Pesticides, and Toxic Substances

Problem Formulation for the Ecological Risk and Drinking Water Exposure Assessments in Support of the Registration Review of Glyphosate and Its Salts



Glyphosate (CAS 1071-83-6)
N-(phosphonomethyl)glycine

Prepared by:
Pamela Hurley, Ph.D. Toxicologist
Michael Lowit, Ph.D. Ecologist
James Hetrick, Ph.D. Senior Scientist
Reviewed by:
Dana Spatz, Branch Chief

U. S. Environmental Protection Agency
Office of Pesticide Programs
Environmental Fate and Effects Division
Environmental Risk Branch III
1200 Pennsylvania Ave., NW
Mail Code 7507P
Washington, DC 20460

Date
June 5, 2009

Table of Contents

I. Purpose

The purpose of this problem formulation is to provide a better understanding of the environmental fate and ecological effects of the registered uses of glyphosate (*N*-(phosphonomethyl)glycine) and its salts. The problem formulation is based on a bridging strategy linking the dissociation of glyphosate salts to the formation of glyphosate acid and its counter ion. The active ingredient is glyphosate acid and application rates will be referred to in this problem formulation in terms of acid equivalents (ae). Glyphosate is a non-selective, systemic herbicide widely used to control weeds in agricultural crops and non-agricultural sites. This document will provide a plan for analyzing data relevant to glyphosate and for conducting updated ecological risk and drinking water assessments for its registered uses. Additionally, this problem formulation is intended to identify remaining data gaps, uncertainties and potential assumptions used to address those uncertainties relative to characterizing the ecological risk associated with the registered uses of glyphosate.

II. Nature of Regulatory Action

The Food Quality Protection Act of 1996 mandated the EPA to implement a new program for assessing the risks of pesticides, *i.e.*, registration review.[1] All pesticides distributed or sold in the United States generally must be registered by EPA. The decision to register a pesticide is based on the consideration of scientific data and other factors showing that it will not cause unreasonable risks to human health, workers, or the environment when used as directed on product labeling. The Registration Review program is intended to ensure that, as the ability to assess risk evolves and as policies and practices change, all registered pesticides continue to meet the statutory standard of no unreasonable adverse effects to human health and the environment. Changes in science, public policy, and pesticide use practices will occur over time. Through the new Registration Review program, the Agency periodically reevaluates pesticides to ensure that as change occurs, products in the marketplace can be used safely.

As part of the implementation of the new Registration Review program pursuant to Section 3(g) of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), the Agency is beginning its evaluation to determine whether glyphosate continues to meet the FIFRA standard for registration. This problem formulation for the environmental fate and ecological risk assessment chapter in support of the registration review is intended for the initial docket opening for the public phase of the review process.

A. Conclusions from Previous Risk Assessments

The ecological risks associated with use of glyphosate as an herbicide have been assessed several times since 1974 when it was first registered for use in the United States. Findings from relevant ecological risk assessments are briefly summarized below.

- Glyphosate was assessed for the Reregistration Eligibility Decision in 1993. The Agency concluded that direct risks to birds, mammals, invertebrates and fish would be minimal.

[1] http://www.epa.gov/oppsrrd1/registration_review/

Under certain conditions, aquatic plants were expected to be at risk from glyphosate use. Additional data were needed for non-target terrestrial plants, including incident data and vegetative vigor testing on non-target terrestrial plants. The assessment stated that many endangered plants may be at risk from use of glyphosate with the registered use patterns. In addition, it was determined that the Houston Toad may be at risk from use of glyphosate on alfalfa.

- In 2003, the USDA Forest Service conducted a risk assessment for glyphosate uses in Forest Service vegetation management programs (USDA, 2003). For forestry uses, all commercial formulations of glyphosate contained the isopropylamine salt of glyphosate (IPA). Application rates ranged from 0.5 lbs a.e./A to 7 lbs a.e./A with the most typical at 2 lb a.e./A. The USDA assessment did not conduct a separate assessment for amphibians. The document concluded that the amphibian data indicated that glyphosate is no more toxic to amphibians than it is to fish. The USDA risk assessment also used a "relative potency" method to estimate the chronic NOAEC for fish in more sensitive species. This appears to be similar to the Agency's acute to chronic ratio estimations. The NOAEC from a less sensitive fish study was divided by 10 to provide a NOAEC for a more sensitive fish. A similar approach was used for an estimation of a chronic NOAEC for glyphosate formulations on freshwater fish and invertebrates. Finally, as a note, some of the endpoints utilized in the USDA risk assessment were not the same endpoints as used in the Agency risk assessments. For example, the chronic mammal endpoint is also used as the acute endpoint for mammals (175 mg/kg from the developmental study in rabbits).

  Based on the available data, the USDA concluded that risks were minimal for mammals, birds, fish, invertebrates and aquatic plants. Risks to fish following application of the more toxic formulations were not considered to be high; however, the assessment did state that at an application rate of 7 lb a.e./A, the acute exposures slightly exceeded the acute LC_{50} for a more tolerant freshwater fish and exceeded it by a factor of 2 for the less tolerant fish. These values were estimated from a worst-case scenario where there was a severe rainfall of (about 7 inches over a 24-hour period) in an area where runoff is favored. For terrestrial plants, the assessment concluded that for relatively tolerant plants, when a low-boom spray is utilized as the method of application, there is no indication that glyphosate would result in damage from spray drift at distances from the application site of 25 feet or greater. For more sensitive plants, the distance increased to approximately 100 feet. For applications requiring the use of backpack-directed spray, the distances would be less. No risks to terrestrial plants from runoff were expected.

- In 2004, the Agency assessed glyphosate's potential to affect 11 federally listed Pacific salmonids. That assessment determined that use of glyphosate "may affect, but is not likely to adversely affect" the species based on acute toxicity to fish for uses with application rates above 5 lb ai/A. For uses with application rates below 5 lb ai/A, the Agency determined glyphosate would have no effect on the 11 subject species.

- In 2006, the Agency assessed glyphosate for a new use on bentgrass (0.74 lb a.i./A) and for new uses on Indian mulberry (noni), dry peas, lentils, garbanzo, safflower and sunflower with the highest proposed ground application rate of 3.73 lbs ae/A. For all proposed new uses, the Agency concluded that there was minimal risk of direct acute effect to terrestrial animals (birds and mammals) and aquatic animals (fish, amphibians, and invertebrates) and minimal risk to terrestrial plants (both non-target and endangered plant species), aquatic non-vascular (algae and diatoms) and vascular (duckweed) plants from off target spray drift and runoff from ground-based application technology. In addition, there were no chronic risks to animals.

- In 2008, the Agency evaluated potential direct and indirect effects of glyphosate on the California red-legged frog *(Rana aurora draytonii)* (CRLF) arising from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) regulatory actions regarding use of glyphosate and its salts on agricultural and non-agricultural sites.

  This effects determination concluded that there are no direct effects on the aquatic-phase CRLF for any of the terrestrial or aquatic uses. The terrestrial-phase CRLF eating broadleaf plants, small insects and small herbivorous mammals may be at risk on a dietary-basis to direct effects following chronic exposure to glyphosate at application rates of 7.5 lb a.e./A and above (forestry, areas with impervious surfaces and rights of way). In addition, terrestrial phase amphibians may be at risk following acute exposure to one particular formulation (Registration No. 524-424), at application rates of 1.1 lbs formulation/A and above (ornamental lawns and turf and industrial outdoor uses). Indirect effects to the aquatic-phase CRLF, based on reduction in the prey base, may occur with aquatic nonvascular plants with aquatic weed management uses at an application rate of 3.75 lb a.e./A. Indirect effects to the terrestrial-phase CRLF, based on reduction in the prey base, may occur with: small insects at any registered rate; large insects at an application rate of 7.95 lb a.e./A (forestry uses); terrestrial phase amphibians following chronic exposure at application rates of 7.5 lb a.e./A and above following acute exposure to one formulation at application rates of 1.1 lbs formulation/A and above; and, mammals following chronic exposure at application rates of 3.84 lbs a.e./A and above (i.e., many crops, forestry, rights of way and areas with impervious surfaces).

  Indirect effects to both the aquatic-and terrestrial-phase CRLF, based on habitat effects, may occur with aquatic non-vascular plants following aquatic weed management use and with aquatic emergent plants and terrestrial plants exposed via spray drift with aerial application at rates of 3.75 lbs/A and above and with ground applications at a rate of 7.95 lbs/A.

- On February 5, 2009, the registrant (Monsanto Company) submitted a 25 volume national endangered species assessment entitled "The Analysis of Possible Risk to Threatened and Endangered Species Associated With Use of Glyphosate-Containing Herbicides in Roundup Ready Crop Protection (Alfalfa, Canola, Corn, Cotton, Soybeans and Sugar Beets." The information in this assessment will be considered as the Agency develops its ecological risk assessment and endangered species effects determination for Registration Review.

III. Stressor Source and Distribution

A. Mechanism of Action

Glyphosate acid (CAS number 1071-83-6) [*N*-(phosphonomethyl)glycine] is an herbicide belonging to the phosphanoglycine class of pesticides. Glyphosate is a foliar, non-selective, systemic herbicide widely used to control weeds in agricultural crops and non-agricultural sites. Glyphosate is a potent and specific inhibitor of the enzyme 5-enolpyruvylshikimate 3-phosphate (ESPS) synthase. This enzyme is the sixth enzyme on the shikimate pathway and it is essential for the biosynthesis of aromatic amino acids (e.g., tyrosine, tryptophan, and phenylalanine) and other aromatic compounds in algae, higher plants, bacteria and fungi. Inhibition of this enzyme leads to plant cell death. The shikimate pathway is absent in mammals.

B. Overview of Pesticide Usage

Glyphosate is used as a non-selective foliar systemic herbicide in both aquatic and terrestrial environments on a wide variety of food and feed crops, non-food and non-feed crops and for other uses including forestry, greenhouse, non-crop, and residential. Based on usage data provided by the Biological and Economic Analysis Division (BEAD), on average, roughly 135,000,000 pounds of glyphosate are applied annually to agricultural crops **(Table 1)**. Glyphosate usage is highest on soybeans, with annual average applications of 68,400,000 lbs a.i. applied (representing nearly 51% of the total use on agricultural crops). The crop with the highest average percent crop treated with glyphosate is soybeans (90%), followed by almonds, grapefruit, and oranges (85%).

Table 1. Screening Level Estimates of Agricultural Uses of Glyphosate
(Source: BEAD SLUA report December 12, 2008)

Crop	Lbs. A.I.	Percent Crop Ttd.	
		Avg.	Max.
Alfalfa	200,000	<2.5	<2.5
Almonds	1,700,000	85	90
Apples	500,000	50	65
Apricots	20,000	50	70
Artichokes	<500	5	15
Asparagus	30,000	45	70
Avocados	100,000	55	65
Barley	300,000	15	25
Beans, Green	50,000	10	20
Beets (NPUD '02)	<500	NC	5
Blackberries	<500	<2.5	5
Blueberries	9,000	25	30
Broccoli	4,000	<2.5	<2.5
Cabbage	7,000	5	20
Caneberries	5,000	10	15
Canola/Rapeseed	500,000	70	80
Cantaloupes	10,000	10	25
Carrots	2,000	5	10
Cauliflower	3,000	<2.5	5
Celery	1,000	5	10
Cherries	200,000	55	75
Corn	24,200,000	30	60
Cotton	16,300,000	75	95
Cranberries (NPUD '02)	20,000	NC	75
Cucumbers	20,000	15	25
Dates	3,000	20	25
Dry Beans/Peas	200,000	15	25
Fallow, Summer	5,400,000	40	60
Figs	8,000	40	70
Flax (NPUD '02)	40,000	NC	15
Garlic	6,000	20	40
Grapefruit	400,000	85	95
Grapes	1,300,000	65	80
Hay, Other (NPUD '02)	90,000	NC	<1
Hazelnuts (Filberts)	20,000	55	80
Kiwifruit	3,000	25	35
Lemons	200,000	70	90
Lettuce	10,000	<2.5	10
Millet (NPUD '02)	3,000	NC	5
Mint (NPUD '02)	2,000	NC	10
Nectarines	40,000	60	70
Oats	100,000	5	10
Olives	10,000	35	45
Onions	30,000	25	40
Oranges	3,200,000	85	90
Parsley (NPUD '02)	<500	NC	10
Pastureland	700,000	<1	<2.5
Peaches	200,000	50	60
Peanuts	200,000	15	30
Pears	100,000	60	80

Crop	Lbs. A.I.	Percent Crop Ttd.	
		Avg.	Max
Peas, Green	20,000	10	20
Pecans	500,000	40	45
Peppers	10,000	15	25
Pistachios	300,000	80	90
Plums	30,000	50	70
Pomegranates (NPUD '02)	10,000	NC	100
Potatoes	70,000	5	15
Prunes	200,000	65	80
Pumpkins	20,000	20	25
Rice	500,000	20	35
Safflower (NPUD '02)	6,000	NC	5
Seed Crops (NPUD '02)	2,000	NC	<1
Sod (NPUD '02)	40,000	NC	10
Sorghum	1,800,000	25	45
Soybeans	68,400,000	90	100
Spinach	1,000	<2.5	5
Squash	9,000	15	30
Strawberries	9,000	10	25
Sugar Beets	100,000	10	20
Sugarcane	200,000	40	50
Sunflowers	700,000	40	50
Sweet Corn	70,000	15	20
Sweet Potatoes (NPUD '02)	1,000	NC	<1
Tangelos	20,000	75	80
Tangerines	50,000	65	80
Tobacco	4,000	<2.5	<2.5
Tomatoes	100,000	30	45
Walnuts	600,000	70	85
Watermelons	20,000	10	20
Wheat	4,400,000	10	25
Wild Rice (NPUD '02)	<500	NC	<1

All numbers rounded.
<500 indicates less than 500 pounds of active ingredient.
<2.5 indicates less than 2.5 percent of crop is treated.
<1 indicates less than 1 percent of crop is treated.

The survey data included in the SLUA report does not differentiate between which exact chemical code(s) are included from the Case.

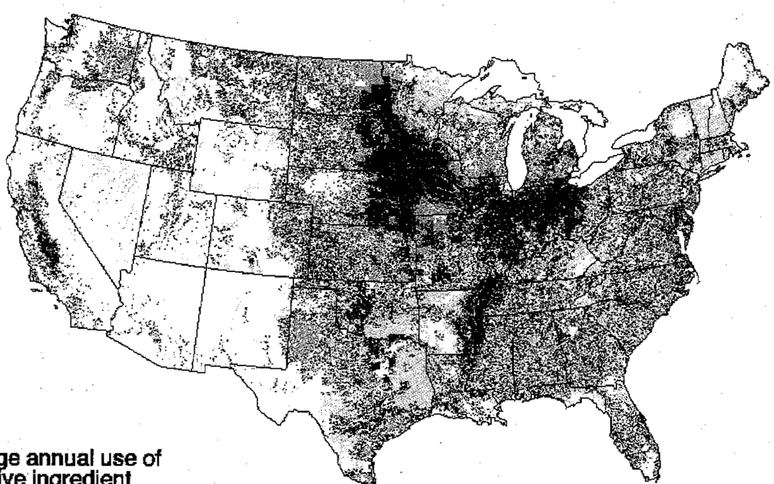
SLUA data sources include:
USDA-NASS (United States Department of Agriculture's National Agricultural Statistics Service),Private Pesticide Market Research, NPUD 2002 (National Pesticide Use Database)of the CropLife America Foundation, and California DPR data.
These results reflect amalgamated data developed by the Agency and are releasable to the public.

(Data years 2001 to 2007)

As shown in **Figure 1**, based on U.S. Geological Survey (USGS) National Water Quality Assessment Program (NAWQA) data from 2002, glyphosate is used on agricultural crops across most of the U.S. but predominantly in California, Midwestern states, Arkansas, Tennessee, Mississippi, Louisiana, and Southeastern states from Maryland to Florida. The use of glyphosate on soybeans represents about 70% of the national use.

GLYPHOSATE - herbicide

2002 estimated annual agricultural use



Average annual use of active ingredient (pounds per square mile of agricultural land in county)

- no estimated use
- 0.001 to 0.499
- 0.5 to 3.445
- 3.446 to 14.669
- 14.67 to 47.984
- >= 47.985

Crops	Total pounds applied	Percent national use
soybeans	70699653	69.49
corn	7491973	7.36
cotton	7063492	6.94
wheat for grain	3509151	3.45
cropland in summer fallow	2514196	2.47
citrus fruit	2186741	2.15
sorghum	1596879	1.57
rice	1057534	1.04
almonds	867188	0.85
grapes	711121	0.70

Figure 1. Map of Estimated Annual Agricultural Use of Glyphosate in 2002
(Source: http://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=02&map=m1099)

Application information for glyphosate is summarized in **Appendix A**. The summary is based on only glyphosate acid. Five salts of glyphosate will be considered at a future date once questions about the conversion of those salts to acid equivalents of glyphosate have been resolved. Target pests include a broad spectrum of emerged grass and broadleaf weeds, both annual and perennial. Glyphosate is formulated as water-dispersible granules (DF) (80% active ingredient), emulsifiable concentrate (EC) (13.4% - 36.5% active ingredient), water-dispersible liquids (L) (5% - 14.6% active ingredient), ready to use (RTU) (0.81% active ingredient), and soluble concentrate/solid (SC/S) (95.2% - 96.7% active ingredient). Application equipment includes aircraft and various ground equipment (boom sprayer, hand held hydraulic sprayer, hand held sprayer, high volume ground sprayer, hooded sprayer, hose-end sprayer, low volume ground sprayer, low volume sprayer, motor driven sprayer, product container, ready-to-use spray container, shielded applicator, sprayer, tank-type sprayer, wick applicator, and wiper applicator). Application is via band treatment, broadcast, crack and crevice treatment, directed spray, edging treatment, ground spray, high volume spray (dilute), low volume spray (concentrate), perimeter treatment, soil broadcast treatment, spot treatment, spray, strip treatment, stump treatment, and wipe-on/wiper treatment. Single application rates range from 0.154 to 7.93 pounds active ingredient/acre (lbs a.i./A) and seasonal application rates are up to 11.05 lbs a.i./A. For some uses, the single application rates are up to 18.99 lbs a.i./A, however, these applications are intended for spot treatment or treatment over areas much smaller than an acre. In these cases the application rate is also expressed in terms of the smaller coverage area.

C. Environmental Fate and Transport

Glyphosate [*N*-(phosphonomethyl)glycine] is an acid, and it can also be associated with different counter cations to form salts. Several salts of glyphosate are currently marketed, as well as the acid, and are considered as the active ingredient in end-use products. The parent acid is the chemical species that exhibits herbicidal activity and so is the actual chemical stressor considered in this problem formulation regardless of the salt, unless otherwise specified. In order to have comparable results, each salt is considered in terms of its glyphosate equivalent, (acid equivalent; ae), determined by multiplying the application rate by the acid equivalence ratio, defined as the ratio of the molecular weight of *N*-(phosphonomethyl)glycine to the molecular weight of the salt. **Table 2** shows the salts of glyphosate that may be used as the source of the actual herbicide-active chemical species. Products that no longer have active registrations are included as well for reference purposes. For the purpose of this assessment, the acid and all salt species are referred to collectively as "glyphosate" throughout this document.

Table 2. Identification of Glyphosate and its Salts

Counter Cation	PC Code	CAS No.	Acid Equivalence Ratio
Glyphosate acid (no counter cation)	417300	1071-83-6	1
Isopropyl amine	103601	38641-94-0	0.74
Monoammonium	103604	114370-14-8	0.94
Diammonium	103607	40465-66-5	0.83
N-methylmethanamine	103608	34494-07-7	0.79
Potassium	103613	39600-42-5; 70901-20-1	0.81
Sesquisodium	103603	70393-85-0	Inactive Registration
Ethanolamine	103605	Technical Product	Active Registration
Trimethyl sulfonium	128501	81591-81-3	Inactive Registration

Surfactants

In some end use products, the active ingredient is formulated with a surfactant to improve efficacy. Studies show that these formulated products can be more toxic than the active ingredient alone and so the formulated products are considered independently of those containing only the active ingredient.

Surfactants ("surface acting agent") are wetting agents that lower the surface tension of a liquid, allowing easier spreading, and lower the interfacial tension between two liquids. Usually they are organic chemicals that contain a hydrophobic group ("tail") and a hydrophilic group ("head") in the same molecule. For the most part, surfactants are mixtures of the same class with different length of the carbon chain. Usually, the mixture indicates the carbon-chain range in the surfactant (e.g., C10- C14 fraction).

Pesticides of high solubility in water, such as glyphosate, do not "wet" (cover) properly the waxy (hydrophobic) surfaces of plants. To attain proper coverage of plant surfaces and distribution of the herbicide, surfactants are added into the formulation of the pesticide. Proper coverage arises from hydrophobic interactions between the surfactant tail (usually long carbon chains) and the waxy surfaces of plants. Therefore, the ecological effects of the pesticide-surfactant combination may differ from that of the single pesticide or the single surfactant. Glyphosate labels also recommend using a nonionic surfactant in the tank mix to further enhance the "wettability" of glyphosate.

One class of surfactants used in glyphosate formulations are the polyethoxylated tallow amines (POEA). However, other formulations may contain a different class of surfactant. The nature of the surfactant included in the formulation is considered to be Confidential Business Information (CBI) and is not included on product labels.

Physical and Chemical Properties of Glyphosate

The physical and chemical properties of glyphosate are shown in **Table 3**. Based on these physical and chemical properties alone, glyphosate has low potential to volatilize from soils (vapor pressure) or from water (Henry's Law Constant). It is also unlikely to bioaccumulate in fish given the low value of the Log *n*-octanol/water partition coefficient. **Appendix B** provides the structure and further chemical/molecular information on glyphosate. The molecular structure characteristics of glyphosate are important as they help understanding its mode of action at a molecular level as well as the binding of glyphosate to soil/sediment particulates.

Table 3. Physical and Chemical Properties of Glyphosate

Physical/Chemical Property	Value
Molecular Formula	$C_3H_8NO_5P$
Molecular Weight	170.8 g/mole
Melting Point	210-212° C (tech.) 215-219° C (pure)
Solubility in water, 25° C	12,000 mg L^{-1}
Vapor Pressure, Pa	1.3×10^{-7} (25° C)
Henry's Law Constant, Pa $\cdot m^3 \cdot mol^{-1}$	2.1×10^{-9}
Log K_{ow}	< -3
Dissociation Constants	$pKa_1 = 0.8$ $pKa_2 = 2.35$ $pKa_3 = 5.84$ $pKa_4 = 10.48$

Environmental Fate Properties of Glyphosate

Table 4 summarizes the environmental fate behavior of glyphosate in different media. The environmental fate data shown in this Table are taken from required studies submitted in support of registration of glyphosate.

The major route of transformation of glyphosate identified in laboratory studies is microbial degradation. In soils incubated under aerobic conditions, the half-life of glyphosate ranges from 1.8 to 5.4 days and in aerobic water-sediment systems is 7 days. However, anaerobic conditions limit the metabolism of glyphosate (half-life 208 days in anaerobic water-sediment systems). In laboratory studies, glyphosate was not observed to break down by abiotic processes, such as hydrolysis, direct photolysis in soil, or photolysis in water. In the field, dissipation half-lives were measured to be 2.4 to 160 days (n=6). Glyphosate dissipation appeared to correlate with climate, being more persistent in cold than in warm climates. Along with significant mineralization to carbon dioxide, the major metabolite of glyphosate is aminomethylphosphonic acid (AMPA).

No data are available about the environmental fate behavior of glyphosate salts. It is assumed the glyphosate salts dissociate rapidly to form glyphosate and the counter ion.

Table 4. Environmental Fate Data for Glyphosate

Study	Value	Major Degradates[1], Comments	MRID #
Abiotic Hydrolysis Half-life	Stable (at 25° C for at least 30 days)	None	00108192; 44320642
Direct Aqueous Photolysis	Stable (for at least 30 days)	None	41689101; 44320643
Soil Photolysis Half-life	Stable (for at least 30 days)	Degradation in dark control was equal to that in irradiated samples	44320645.
Aerobic Soil Metabolism Half-life	1.8 and 5.4 days (sandy loam) 2.6 days (silt loam)	AMPA (max 29% at 40 d) CO_2 (≥70% after 1 year)	42372501; 44320645
Anaerobic Aquatic Metabolism Half-life	208 days (Water- silty clay loam sediment system)	AMPA (max 25% at 15 d) CO_2 (≥ 35% after 1 year) Initial degradation was rapid but slowed considerably. Non-linear modeling predicts DT_{50} = 8.1 day and DT_{90} > 1 yr	41723701; 42372502
Aerobic Aquatic Metabolism Half-life	14.1 days (Water- silty clay loam sediment)	AMPA (19-25% at 7-30 d) CO_2 (≥ 23% after 30 d)	41723601; 42372503

Study	Value						MRID #
Batch Equilibrium (mL/g)	*Soil*	*Avg K_d*	*Avg K_{oc}*	*K_F*	*1/n*	*K_{Foc}*	44320646
	sand	170	58,000	64	0.75	22,000	
	sandy loam	18	3,100	9.4	0.72	1,600	
	sandy loam	230	13,000	90	0.76	5,000	
	silty clay loam	680	33,000	470	0.93	21,000	
	silty clay loam	1,000	47,000	700	0.94	33,000	

Study	Value		MRID #
Terrestrial Field Dissipation Half-life	Glyph. / AMPA 1.7 d / 131 d (TX) 7.3 d / 119 d (OH) 8.3 d / 958 d (GA) 13 d / 896 d (CA) 17 d / 142 d (AZ) 25 d / 302 d (MN) 114 d / 240 d (NY) 142 d / no data (IA)	Bare ground studies. Glyphosate and AMPA were found predominantly in the 0 to 6 inch layers	42607501; 42765001
Aquatic Field Dissipation	7.5 days	In a farm pond in Missouri. At 3 sites (OR, GA, MI), half-lives could not be calculated due to recharging events.	40881601
	Water: Dissipated rapidly immediately after treatment. Sediment: Glyphosate remained in pond sediments at ≥ 1 ppm at 1 year post treatment.	In ponds in Michigan and Oregon and a stream in Georgia Accumulation was higher in the pond than in the stream sediments	41552801.
Forestry Dissipation	Foliage: < 1 day Ecosystem: Glyphosate: 100 d AMPA: 118 d	3.75 lb ae/A, aerial application	41552801.

[1] Major degradates are defined as those which reach >10% of the applied.

Environmental Transport Mechanisms of Glyphosate

The available field and laboratory data indicate that both glyphosate and AMPA adsorb strongly to soil. Soil partitioning coefficients (K_d) measured in batch equilibrium studies ranged from 18 to 1000 mL/g, with corresponding organic carbon partitioning coefficients (K_{oc}) of 3100 to 58000 mL/g_{oc}. The coefficient of variation for K_{oc} is less than the coefficient of variation for K_d, indicating that pesticide binding to the organic matter fraction of the soil explains some of the variability among the adsorption coefficients, and that K_{oc} is therefore the appropriate parameter to use in determining the soil mobility of the compound. Based on measured K_{oc} values, glyphosate is classified as slightly mobile to hardly mobile according to the FAO classification scheme and would not be expected to leach to groundwater or to move to surface water at high levels through dissolved runoff. However, glyphosate does have the potential to contaminate surface water from spray drift or transport of residues adsorbed to soil particles suspended in runoff.

The potential for volatilization of glyphosate from soil and water is expected to be low due to the low vapor pressure and low Henry's Law constant. Interestingly, several studies have shown both glyphosate and AMPA detections in rainwater near use locations. In most cases, these detections were found during the spraying season in the vicinity of local use areas and can be attributed to spray drift rather than to volatilization or long range transport (Baker et al., 2006; Quaghebeur et al., 2004). The highest concentrations were found in urban locations. At one site in Belgium that was 5 m from a spraying location in an urban parking lot, glyphosate was detected in rainwater for several months following a single application (Quaghebeur et al., 2004). Deposition was measured to be 205 µg a.i./m^2 at one week after spraying and 0.829 µg/m^2 two months after spraying. These data suggest that volatilization of glyphosate from hard surfaces is possible despite its low vapor pressure.

Monitoring Data

Agricultural Uses

A total of 154 water samples were collected by the U.S. Geological Survey during a 2002 study in nine Midwestern States (Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin) (Scribner et al., 2003 and Lee et al., 2001), where glyphosate is extensively used on corn.

Glyphosate was detected in 36 percent of the samples, while its metabolite aminomethylphosphonic acid (AMPA) was detected in 69 percent of the samples. The highest measured concentration of glyphosate was 8.7 ug/Lr, well below the Maximum Contaminant Level, MCL, of 700 micrograms per liter. The highest AMPA concentration was 3.6 ug/L, but there is no MCL for AMPA.

Median concentrations (mg/L) detected for each runoff period at the sampling sites are:

Analyte	**Pre-emergence**	**Post-emergence**	**Harvest season**
Glyphosate	<0.10	<0.10	<0.10
AMPA	0.10	0.27	0.21

Urban Uses

In 2002, treated effluent samples were collected from 10 wastewater treatment plants (WWTPs) in Arizona, Colorado, Georgia, Iowa, Minnesota, Nevada, New Jersey, New York, and South Dakota to study the occurrence of glyphosate and AMPA (Kolpin et al., 2006). Stream samples were collected upstream and downstream of the 10 WWTPs. Two reference streams were also sampled. The results document the apparent contribution of WWTP effluent to stream concentrations of glyphosate and AMPA, with roughly a two-fold increase in their frequencies of detection between stream samples collected upstream and those collected downstream of the WWTPs. Thus, urban use of glyphosate contributes to glyphosate and AMPA concentrations in streams in the United States.

Glyphosate or its degradate AMPA were commonly detected in the stream and WWTP effluent samples, being present in 67.5% of the 40 samples collected. Concentrations were generally low, although nine detections of AMPA (maximum concentration=3.9 µg/L) and three detections of glyphosate (maximum concentration=2.2 µg/L) exceeded 1 µg/L. AMPA was detected much more frequently (67.5%) than glyphosate (17.5%).

Both AMPA and glyphosate had the greatest frequency of detection in the WWTP effluent samples, with roughly a two-fold increase in the frequency of detection for both AMPA and glyphosate between stream samples located upstream and those located downstream of the WWTPs.

It should be noted, however, that AMPA can also be derived from the degradation of phosphonic acids (such as EDTMP and DTPMP) in detergents. Thus, part of the AMPA detections from this study could be potentially derived from a detergent source. Other components of detergents, such as 4-nonylphenol diethoxylate and 4-nonylphenol monoethoxylate were also measured in the samples collected for this study. However, AMPA was always present in samples that had detections of glyphosate, which suggests that at least part of the AMPA concentrations in this study were derived from the degradation of glyphosate.

Analytical Chemistry Method Used in the U.S .Geological Survey Studies

The Survey developed and analytical chemistry method for the determination of glyphosate and AMPA in water (Lee et al., 2001). The method consists of a pre-column derivatization with 9-flurenylmethylchlorformate, followed by clean-up and concentration (online solid-phase extraction) prior to direct injection into a liquid chromatograph/mass spectrometer (LC/MS). The method detection limits (MDLs) were 0.084 μgL^{-1} for glyphosate and 0.078 μgL^{-1}. The method reporting limits (MRLs) were set at 0.1 μgL^{-1} for both analytes.

IV. Receptors

Consistent with the process described in the Overview Document (USEPA, 2004), the risk assessment for glyphosate will rely on a surrogate species approach. Toxicological data generated from surrogate test species, which are intended to be representative of broad taxonomic groups, are used to extrapolate to potential effects on a variety of species (receptors) included under these taxonomic groupings.

Acute and chronic toxicity data from studies submitted by pesticide registrants along with the available open literature are used to evaluate the potential direct and indirect effects of glyphosate on aquatic and terrestrial receptors. Toxicity studies for the technical grade active ingredient (TGAI), the typical end-use product (TEP), and the AMPA degradate will all be considered in the ecological risk assessment. Open literature studies are identified using EPA's ECOTOX database[2], which employs a literature search engine for locating chemical toxicity data for aquatic life, terrestrial plants, and wildlife. Research papers accepted into the ECOTOX database are screened using standard procedures to ensure consistent, high quality information; these studies will be considered during the 'Analysis' phase of risk assessment process. The Incident Data System (IDS), which tracks incident reports submitted to EPA, is used to identify supportive, line of evidence information on exposure of aquatic and terrestrial receptors. Data from all of these sources can also provide insight into the direct and indirect effects of glyphosate on biotic communities from loss of species that are sensitive to the chemical and from changes in structure and functional characteristics of the affected communities.

[2] http://www.epa.gov/ecotox

A. Effects to Aquatic Organisms

Table 5 summarizes the most sensitive aquatic toxicity endpoints of glyphosate and/or its salts. Data gaps for glyphosate include chronic marine/estuarine fish and invertebrates studies. A chronic toxicity value (NOAEC) can be estimated for both marine/estuarine fish and invertebrates using an acute to chronic ratio. For fish, the estimate can be calculated from the acute and chronic freshwater fish data and the acute marine/estuarine fish data. For invertebrates, the estimate can be calculated from the acute and chronic freshwater invertebrate data and the acute marine/estuarine invertebrate data.

Table 5. Aquatic Toxicity Profile for Glyphosate and/or Its Salts

Assessment Endpoint	Species	Toxicity Values	Toxicity Category[1]	Citation MRID # /Date	Comment
Acute Toxicity to Freshwater Fish	Bluegill sunfish (*Lepomis macrochirus*)	96-hr. LC_{50}: 43 mg a.e./L*	Slightly toxic	44320630/1995	
Chronic Toxicity to Freshwater Fish	Fathead minnow (*Pimephales promelas*)	NOAEC: 25.7 mg a.e./L (highest concentration tested)		00108171/1975	
Acute Toxicity to Freshwater Invertebrates	Midge (*Chironomus plumosus*)	48-hr LC_{50}: 53.2 mg a.e./L	Slightly toxic	00162296/1979	
Chronic Toxicity to Freshwater Invertebrates	Water flea (*Daphnia magna*)	NOAEC: 49.9 mg a.e./L		00124763/1982	LOAEC: 95.7 mg a.e./L based on reduced reproductive capacity.
Acute Toxicity to Marine/Estuarine Fish	Sheepshead minnow (*Cyprinodon variegatus*)	96-hr. LC_{50}: 240 mg a.e./L	Practically nontoxic	44320632/1996	
Acute Toxicity to Marine/Estuarine Invertebrates	Mysid (*Americamysis bahia*)	LC_{50}: 40 mg a.e./L	Slightly toxic	44320634/1996	
Acute Toxicity to Non-vascular Aquatic Plants	Green algae (*Selenastrum capricornutum*)	4-day EC_{50}: 12.1 mg a.e./L		40236901/1987	
Acute Toxicity to Toxicity to Vascular Aquatic Plants	Duckweed (*Lemna gibba*)	14-day EC_{50}: 11.9 mg a.e./L		44320638/1996	

*a.e. = expressed in terms of acid equivalents for glyphosate

[1]Categories of **acute toxicity for aquatic organisms** (U.S. EPA, 2004) based on LC_{50} (mg/L): < 0.1 very highly toxic; 0.1-1 highly toxic; >1-10 moderately toxic; >10-100 slightly toxic; >100 practically nontoxic. Toxicity categories for aquatic plants have not been defined.

Table 6 summarizes the most sensitive aquatic toxicity endpoints of glyphosate formulations. Some glyphosate formulations have been found to be more toxic to aquatic organisms than technical glyphosate. Formulations containing one class of surfactants, polyethoxylated tallow amines (POEA) tend to be the most toxic to aquatic organisms. Only a few ecological effects studies have been conducted with formulations containing surfactants other than POEA. The toxicities of some of these formulations appear to be either similar to or less toxic than the technical material. However, there are some non-POEA formulations that appear to be quite a bit more toxic than the technical material. For most formulations, we have no data. There is an uncertainty associated with formulations registered for aquatic uses and whether or not they contain POEA-type surfactants or other surfactants that are more toxic than technical glyphosate.

Table 6. Freshwater Aquatic Toxicity Profile for Glyphosate Formulations

Assessment Endpoint	Species	Toxicity Value	Toxicity Category[1]	Citation MRID # /Date	Comment
Acute Toxicity to Freshwater Fish	Rainbow trout (*Oncorhynchus mykiss*)	96-hr LC_{50}: 3.17 ppm formulation[2]	Moderately toxic	40098001/1986	Roundup: 30% a.i.
Acute Toxicity to Freshwater Invertebrates	Water flea (*Daphnia magna*)	48-hr EC_{50}: 3 ppm formulation[2]	Moderately toxic	00162296/1979	Roundup: Glyphosate IPA salt (41% a.i.)
Acute Toxicity to Marine/Estuarine Fish	Sheepshead minnow (*Cyprinodon variegatus*)	96-hr. LC_{50}: >180.2 ppm formulation[3]	Practically nontoxic	45374005/2000	Glyphosate SL formulation (28.3% a.i.)
Acute Toxicity to Marine/Estuarine Invertebrates	Pacific oyster (*Crassostrea gigas*)	48-hr. EC_{50}: 82 ppm formulation[3]	Slightly toxic	45374006/2000	Glyphosate SL formulation (28.3% a.i.)
Acute Toxicity to Non-vascular Aquatic Plants	Freshwater diatom (*Navicula pelliculosa*)	96-hr EC_{50}: 0.39 ppm formulation[4]		45666701/2001	Glyphosate (glyphos) 31.0% a.i.
Acute Toxicity to Vascular Aquatic Plants	Duckweed (*Lemna gibba*)	14-day EC_{50}: 4.9 ppm formulation[2]		44125714/1984	Roundup: Glyphosate IPA salt (41% a.i.)

[1]Categories of **acute toxicity for aquatic organisms** (U.S. EPA, 2004) based on EC_{50}/LC_{50} (ppm): < 0.1 very highly toxic; 0.1-1 highly toxic; >1-10 moderately toxic; >10-100 slightly toxic; >100 practically nontoxic. Toxicity categories for aquatic plants have not been defined.

[2] Formulation containing POEA surfactant

[3] Formulation not containing POEA surfactants

[4] There are at least two labels with this formulation name. Because the formulations differ, it could not be determined if the formula used in the study was a POEA or non-POEA formulation

Table 7 summarizes submitted acute toxicity studies on freshwater fish with two surfactants, POEA and geronol, an alkyl polyoxy ethylene phosphoric acid ester.

Table 7. Freshwater Fish Acute Toxicity for Surfactants Used with Glyphosate Formulations

Chemical	Species	% a.i.[1]	96-hour LC_{50} (mg/L)	Toxicity Category[2]	MRID #/Year
Polyoxy ethylene fatty amine (POEA)	Rainbow trout (*Oncorhynchus mykiss*)	100	LC_{50}: 1 (1.2 - 1.7)[3]	Highly toxic	00162296/1979
Polyoxy ethylene fatty amine (POEA)	Fathead minnow (*Pimephales promelas*)	100	LC_{50}: 2 (1.5 - 2.7)	Moderately toxic	00162296/1979
Polyoxy ethylene fatty amine (POEA)	Channel catfish (*Ictalurus punctatus*)	100	LC_{50}: 3 (2.5 - 3.7)	Moderately toxic	00162296/1979
Polyoxy ethylene fatty amine (POEA)	Bluegill sunfish (*Lepomis macrochirus*)	100	LC_{50}: 13 (10.0 - 17.0)	Slightly toxic	00162296/1979
Surfactant Geronol CF/AR (alkyl polyoxy ethylene phosphoric acid ester)	Zebra fish (*Brachydanio rerio*)	100	LC_{50}: >100 (N.A.)	Practically non-toxic	44738201/ Summary from another study

[1] a.i. = active ingredient, assumed 100% for technical material
[2]Based on LC_{50} (mg/L): < 0.1 very highly toxic; 0.1-1 highly toxic; >1-10 moderately toxic; >10-100 slightly toxic; >100 practically nontoxic
[3] Range is 95% confidence interval for endpoint.

Table 8 shows the acute aquatic toxicity endpoints for the degradate, aminomethylphosphonic acid (AMPA). Based on this data, AMPA is less acutely toxic to aquatic organisms than the parent, glyphosate.

Table 8. Freshwater Acute Toxicity for Aminomethylphosphonic Acid (AMPA) Degradate of Glyphosate

Chemical	Species	% a.i.[1]	96-hour LC_{50} / EC_{50} (mg/L)	Toxicity Category[2]	MRID #/Year
AMPA	Rainbow trout (*Oncorhynchus mykiss*)	94.38	LC_{50}: 499 (391 - 647)	Practically nontoxic	43334713/1991
AMPA	Water flea (*Daphnia magna*)	94.38	EC_{50}: 683 (553 - 1010)	Practically nontoxic	43334715/1994

[1] a.i. = active ingredient, assumed 100% for technical material
[2]Based on LC_{50} (mg/L): < 0.1 very highly toxic; 0.1-1 highly toxic; >1-10 moderately toxic; >10-100 slightly toxic; >100 practically nontoxic
[3] Range is 95% confidence interval for endpoint.

Table 9 summarizes acute toxicity studies on freshwater invertebrates with two surfactants.

Table 9. Freshwater Invertebrates Acute Toxicity for Surfactants Used with Glyphosate Formulations

Chemical	Species	% a.i.*	48-hour EC_{50} / LC_{50} (mg/L)	Toxicity Category[1]	MRID #/Year
Surfactant Geronol CF/AR (alkyl polyoxy ethylene phosphoric acid)	Daphnia (*Daphnia magna*)	Tech.	EC_{50}: 48	Slightly toxic	44738201/1996
MON 0818 (POEA)	Midge (*Chironomus plumosus*)	100	LC_{50}: 13 (7.1-24.0)[2]	Slightly toxic	00162296/1979

* a.i. = active ingredient, assumed 100% for technical.
[1]Based on LC_{50} (mg/L): < 0.1 very highly toxic; 0.1-1 highly toxic; >1-10 moderately toxic; >10-100 slightly toxic; >100 practically nontoxic
[2] Range is 95% confidence interval for endpoint

B. Effects to Terrestrial Organisms

Table 10 summarizes the most sensitive terrestrial toxicity endpoints for glyphosate. Acceptable acute avian oral toxicity data were not submitted for a passerine species exposed to glyphosate, which is now required under the 40 CFR Part 158 (CFR 40 2008) data requirements for conventional pesticides. This is a data gap for glyphosate.

Table 10. Terrestrial Toxicity Profile for Glyphosate and/or Its Salts

Endpoint	Species	Toxicity Value	Toxicity Category[1]	Citation MRID#/Date	Comment
Acute Avian Oral Toxicity	Bobwhite quail (*Colinus virginianus*)	LD_{50}: >3196 mg a.e./kg bw	Slightly toxic	00108204/1978	
Acute Avian Dietary Toxicity	Bobwhite quail (*Colinus virginianus*)	LC_{50}: >4971.2 PPM	Slightly toxic	44320628/1997	
Chronic Avian	Bobwhite quail (*Colinus virginianus*)	Reproduction study NOAEC: 830 PPM		108207/1978	LOAEC: >830 PPM (highest concentration tested).
Acute mammalian	Rat (*rattus norvegicus*)	LD_{50} >4800 mg/kg bw	Practically non-toxic	43728003/1989	
Chronic mammalian	Rat (*rattus norvegicus*)	NOAEL: 500 mg/kg bw/day; NOAEC: 10000 ppm		41621501/1990	Reproduction study parental/pup LOAEL: 1500 mg/kg bw/day; LOAEC: 30000 ppm (soft stools, decreased body weight gain and food consumption in parents and decreased body weight gain during lactation in pups).
Acute terrestrial invertebrate	Honey bee (*Apis mellifera*)	48 hr LD_{50} (O): >100 μg/bee		00026489/1972	
Terrestrial Plants	<u>Seedling Emergence</u> Monocots	EC_{25}: >5 LB/A		40159301/1987	
	<u>Seedling Emergence</u> Dicots	EC_{25}: > 5 LB/A		40159301/1987	
	<u>Vegetative</u>	EC_{25}: 0.16 LB/A		44125715/45045	

Endpoint	Species	Toxicity Value	Toxicity Category[1]	Citation MRID#/Date	Comment
	Vigor Monocots			101/ 1995	
	Vegetative Vigor Dicots	EC_{25}: 0.074 LB/A		44320636/1996	

[1] Categories of **acute toxicity to terrestrial animals, avian and mammalian** (U.S. EPA, 2004). **LC_{50} (ppm):** < 50 very highly toxic; 50 - 500 highly toxic; 501 - 1000 moderately toxic; 1001-5000 slightly toxic; >5000 practically non-toxic. **LD_{50} (mg/kg bw)**: < 10 very highly toxic; 10 - 50 highly toxic; 51 - 500 moderately toxic; 501-2000 slightly toxic; >2000 practically non-toxic. Toxicity categories for terrestrial plants have not been defined.

For birds and mammals, the endpoints following acute exposure to glyphosate are not discrete and a quantitative estimate of risk cannot be done. However, for registered formulation products, there is one avian study and 4 mammalian studies with discrete values. For estimation of risk, these studies can be matched with the specific labeled rates and uses. Endpoints for these studies are summarized in **Table 11.**

Table 11. Terrestrial Toxicity Profile for Glyphosate Formulations

Endpoint	Species	Toxicity Value	Toxicity Category[1]	Citation MRID#/Date	Comment
Acute Avian Oral Toxicity	Bobwhite quail (*Colinus virginianus*)	LD_{50}: 1651mg formulation/kg bw (1131 mg a.e./kg bw)	Slightly toxic	45777402/1999	Glyphosate monoammonium salt (MON 14420)
Acute Mammalian Toxicity	Rat (*rattus norvegicus*)	LD_{50}: 3132 mg formulation/kg bw (357 mg a.e./kg bw)	Moderately toxic when reported as a.e.	46714802/2003	HM-2028 (Glyphosate 11.4%)

[1] Categories of **acute toxicity to terrestrial animals, avian and mammalian** (U.S. EPA, 2004). **LC_{50} (ppm):** < 50 very highly toxic; 50 - 500 highly toxic; 501 - 1000 moderately toxic; 1001-5000 slightly toxic; >5000 practically non-toxic. **LD_{50} (mg/kg bw)**: < 10 very highly toxic; 10 - 50 highly toxic; 51 - 500 moderately toxic; 501-2000 slightly toxic; >2000 practically non-toxic. Toxicity categories for terrestrial plants have not been defined.

Based on the available avian toxicity studies, glyphosate is at the most, only slightly toxic. The AMPA degradate is no more toxic than the parent, glyphosate. **Table 12** summarizes these studies.

Table 12. Avian Acute Toxicity for Aminomethylphosphonic Acid (AMPA) Degradate of Glyphosate

Chemical	Species	% a.i.[1]	LD_{50}/ LC_{50} NOAEL/ NOAEC (mg a.e./kg bw or ppm a.e.)[1]	Toxicity Category[2]	MRID #/Year
AMPA	Bobwhite quail (*Colinus virginianus*)	87.8	LD50: >1976 (N.A.) mg/kg NOAEL: 1185	Slightly toxic	43334709/1991
AMPA	Bobwhite quail (*Colinus virginianus*)	87.8	LC50: >4934 (N.A.) PPM NOAEC: 4934	Slightly toxic	43334710/1994
AMPA	Mallard duck (*Anas platyrhynchos*)	87.8	LC50: >4934 (N.A.) PPM NOAEC: 4934	Slightly toxic	43334711/1994

[1] a.i. = active ingredient; a.e. = acid equivalent
[2]Based on LC_{50} (ppm): < 50 very highly toxic; 50 - 500 highly toxic; 501 - 1000 moderately toxic; 1001-5000 slightly toxic; >5000 practically non-toxic; based on LD_{50} (mg/kg bw): < 10 very highly toxic; 10 - 50 highly toxic; 51 - 500 moderately toxic; 501-2000 slightly toxic; >2000 practically non-toxic
[4] Range is 95% confidence interval for endpoint, N.A. = not available

C. Adverse Ecological Incidents

A review of the EIIS database for ecological incidents involving glyphosate and its salts (PC Codes 417300, 103601, 103603, 103604 and 103607) was completed on 08/11/2008. A summary of the results is presented below.

Terrestrial Incidents

Five incident reports for glyphosate isopropylamine salt were filed, 2 in 1993, 1 in 1994, 1 in 1996 and 1 in 2004 for uses on corn, field, home/lawn and a tree farm. One report did not file a specific use. The certainty indices were from unlikely to probable. The incidents considered possibly due to glyphosate were mortality in an unknown quantity of birds from drift, mortality in 3 birds from drift and mortality in several dogs from runoff. The probable incident was incapacitation of two iguanas following ingestion of glyphosate.

Plant Incidents

For glyphosate, 63 incidents were reported for mostly plant damage to a wide variety of plants from either direct treatment or spray drift. The reports were filed from 1992 – 2008 with the certainty code ranging from possible to highly probable. The majority of the reports were either probable or highly probable.

For the isopropylamine salt of glyphosate, 443 incident reports were filed for a wide variety of terrestrial plants, particularly agricultural crops and grass. There were only a few incidents of trees being damaged or killed. The majority of the reports were rated as probable but there were some highly probable incidents and a number of possible incidents. The reports were filed from 1990 – 2006 with a large number of accidental misuses and of unknown legality. Plant damage and mortality were the main issues with drift as the main exposure route.

Aquatic Incidents

For glyphosate, two incident reports were filed in which 1 carp and 1 catfish were incapacitated and 20 goldfish were killed upon ingestion of glyphosate. The certainty index was possible for both incidents. The reports were filed in 2003.

For the isopropylamine salt of glyphosate, 16 incident reports were filed from 1990 – 2003. The certainty indices ranged from unlikely to highly probable. There was one accidental misuse in which thousands of shad were killed upon ingestion. It was not stated what the application method was, but this was the one report that was rated highly probable. Three other misuses were reported and the remainder was either registered uses (majority) or unknown. Eight of the reports were from runoff, 2 ingestion, 1 pond treatment and 1 skin contact. The others were either unknown or not reported. Fifteen reported mortality and 2 reported incapacitation. All of the reports were on fish. The numbers of fish killed ranged from 9 to thousands.

D. Ecosystems at Risk

Glyphosate may be applied as an aerial or ground spray herbicide to terrestrial habitats for agricultural and non-agricultural uses. The ecosystems potentially at risk are often extensive in scope; therefore, it may not be possible to identify specific ecosystems during the development of a nation-wide ecological risk assessment. However, in general terms, terrestrial ecosystems potentially at risk could include the treated field and immediately adjacent areas that may receive drift or runoff. Areas adjacent to the treated field could include cultivated fields, fencerows and hedgerows, meadows, fallow fields or grasslands, woodlands, riparian habitats, and other uncultivated areas.

Glyphosate can be applied to aquatic environments for weed control. It also has the potential to contaminate surface water at application from spray drift and runoff. In general terms, aquatic ecosystems potentially at risk include water bodies adjacent to, or down stream from, the treated field and might include impounded bodies such as ponds, lakes and reservoirs, or flowing waterways such as streams or rivers. For uses in coastal areas, aquatic habitat also includes marine ecosystems, including estuaries.

V. Assessment Endpoints

The most sensitive toxicity endpoints are used from surrogate test species to estimate treatment-related direct effects on acute mortality and chronic reproductive, growth, and survival assessment endpoints. Surrogate aquatic organisms include freshwater and estuarine/marine fish and invertebrates, and surrogate terrestrial animal species include birds and mammals. These tests include short-term acute, subacute, and reproduction studies and are typically arranged in a hierarchical or tiered system that progresses from basic laboratory tests to applied field studies.

For plants in terrestrial and semi-aquatic environments, the screening assessment endpoint is the perpetuation of populations of non-target species (crops and non-crop plant species). When data are available, endpoints assessed include emergence of seedlings and vegetative vigor.

VI. Conceptual Model

A. Risk Hypotheses

Risk hypotheses are specific assumptions about potential adverse effects (i.e., changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (USEPA, 2004). For this assessment, the risk is stressor-initiated, where the stressor is the release of glyphosate to the environment. The following risk hypothesis is presumed for this screening-level assessment:

> *When used in accordance with current labels for terrestrial and aquatic use patterns, glyphosate and its major transformation product AMPA can move off-site via runoff (both dissolved phase and with eroded sediment) and spray-drift and expose non-target organisms. Polyoxy ethylene tallow amine (POEA), a surfactant in some glyphosate formulations, can also move off-site via spray drift and runoff. Application to foliar surfaces and soil may also result in exposure to non-target organisms. Monitoring data indicate detections of glyphosate and/or AMPA in surface waters and near field sites from use areas presumably due to current uses. These potential exposure pathways may result in adverse effects on the survival, growth, and/or reproduction of non-target terrestrial and aquatic organisms, including Federally-listed threatened and endangered species.*

B. Diagram

Direct Terrestrial Uses

The environmental fate properties of glyphosate along with monitoring data identifying its presence in surface waters and rain indicate that runoff via dissolved phase and eroded sediment and spray drift represent potential transport mechanisms of glyphosate to aquatic and terrestrial organisms. As depicted in **Figure 2**, these transport mechanisms (*e.g.* sources) for spray (ground, aerial) applications may result in the movement of glyphosate into aquatic (water) and terrestrial (soil and foliage) habitats. The movement away from the site of application represents exposure pathways for a broad range of biological receptors of concern (non-target animals) and the potential attribute changes, *i.e.*, effects such as reduced survivals, growth, and reproduction in the receptors.

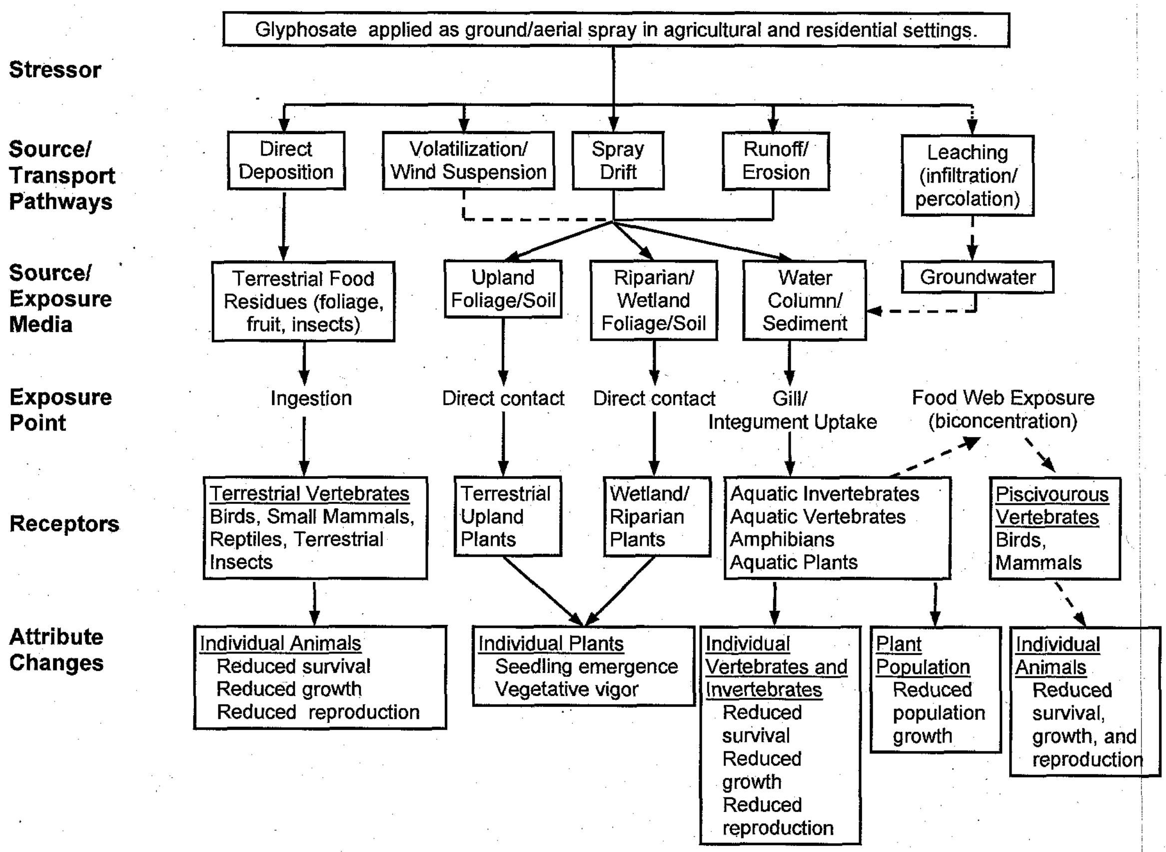


Figure 2. Conceptual model for effects of glyphosate, AMPA, and POEA on non-target aquatic and terrestrial organisms for direct terrestrial use patterns

Direct Aquatic Uses

As depicted in **Figure 3**, glyphosate applied by ground/aerial spray directly to aquatic environments will result in different dissipation and exposure pathways. Direct deposition may result in exposure to drinking water and within any part of the environmental matrix of the aquatic (water column / sediment) and/or semi-aquatic (soil and foliage) application site. The movement away from the site of application in flowing water represents exposure pathways for a broad range of biological receptors of concern (non-target animals) and the potential attribute changes, *i.e.*, effects such as reduced survivals, growth, and reproduction in the receptors.

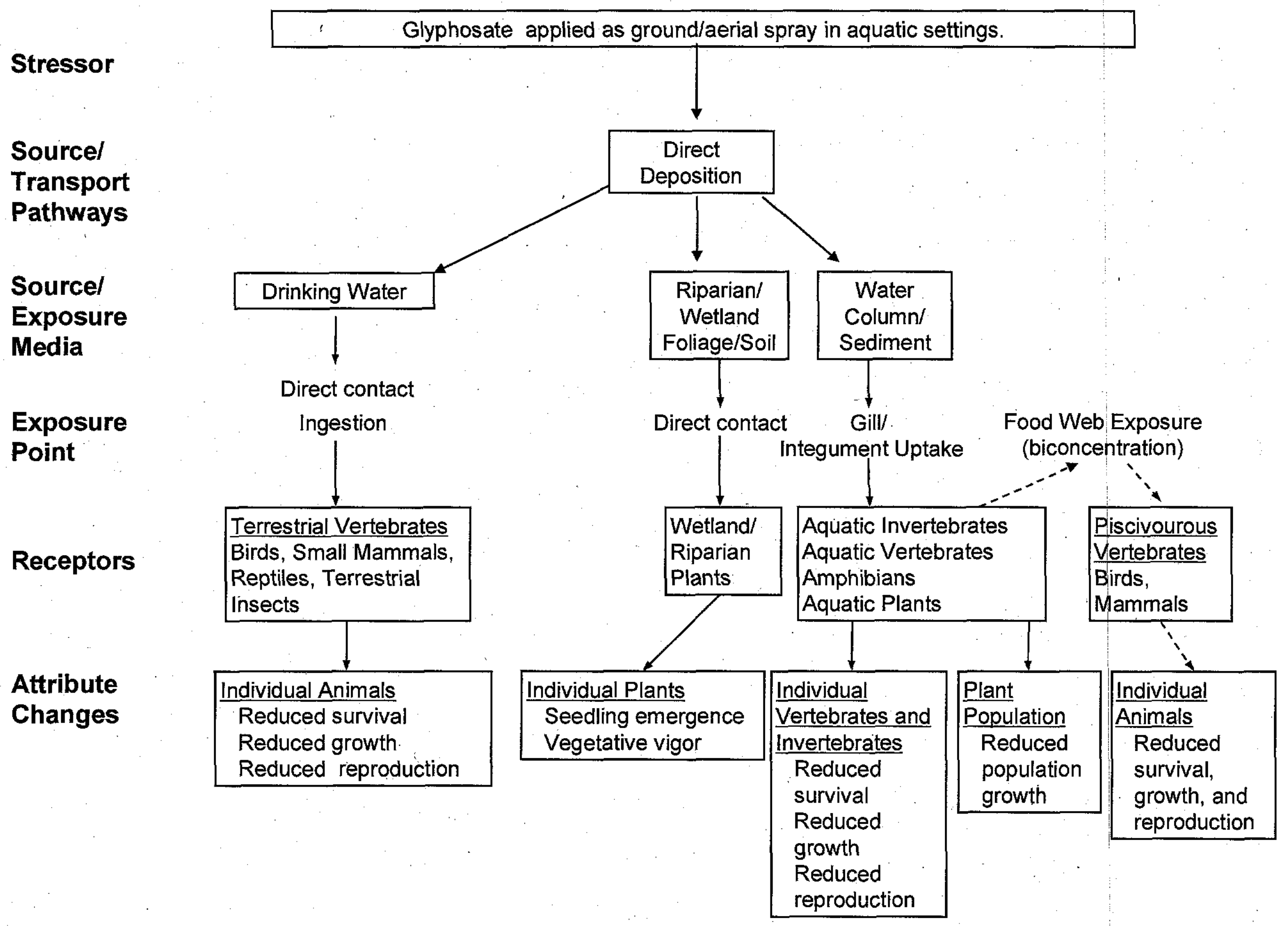


Figure 3. Conceptual model for effects of glyphosate, AMPA, and POEA on non-target aquatic and terrestrial organisms for direct aquatic use patterns

VII. Analysis Plan Options

In Registration Review, pesticide ecological risk assessments will follow the Agency's Guidelines for Ecological Risk Assessment, will be consistent with the paper titled "Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs, U.S. Environmental Protection Agency" ("Overview Document") (January 2004), and will be done in accordance with Section 7 of the Endangered Species Act.

A. Ecological Risk Assessment

Previously completed screening level risk assessments and exceedances of Agency levels of concern indicate direct effects from glyphosate and its salts to aquatic and terrestrial plants. These screening level assessments found minimal risk to avian, mammals, and aquatic organisms.

Direct effects from glyphosate were identified for the terrestrial-phase California Red-Legged Frog (CRLF) eating broadleaf plants, small insects and small herbivorous mammals on a dietary-basis following chronic exposure to glyphosate at application rates of 7.5 lb a.e./A and above (forestry, areas with impervious surfaces and rights of way). In addition, terrestrial phase amphibians may be at risk following acute exposure to one glyphosate formulation at application rates 1.1 lbs formulation and above. Indirect effects to the aquatic-phase CRLF, based on reduction in the prey base, may occur with aquatic nonvascular plants with aquatic weed management uses at an application rate of 3.75 lb a.e./A. Indirect effects to the terrestrial-phase CRLF, based on reduction in the prey base, may occur with: small insects at any registered rate; large insects at an application rate of 7.95 lb a.e./A (forestry uses); terrestrial phase amphibians following chronic exposure at application rates of 7.5 lb a.e./A and above following acute exposure to one formulation at application rates of 1.1 lbs formulation/A and above; and, mammals following chronic exposure at application rates of 3.84 lbs a.e./A and above (i.e., many crops, forestry, rights of way and areas with impervious surfaces). Indirect effects to both the aquatic-and terrestrial-phase CRLF, based on habitat effects, may occur with aquatic non-vascular plants following aquatic weed management use and with aquatic emergent plants and terrestrial plants exposed via spray drift with aerial application at rates of 3.75 lbs/A and above and with ground applications at a rate of 7.95 lbs/A.

Previous screening level risk assessments indicate the degradation product of glyphosate, AMPA, has lower toxicity to aquatic and terrestrial organisms than glyphosate. Therefore, the ecological risk was not evaluated for AMPA. The risk assessment by USDA indicated glyphosate exposure from certain formulations of glyphosate exceed toxicity endpoints for freshwater fish at application rates of 7 lbs ae/A. A toxic component in some glyphosate formulations is the surfactant polyoxy ethylene tallow amine (POEA). POEA and some other surfactants used in glyphosate formulations are more toxic to aquatic organisms than glyphosate.

Uncertainties remaining from previous assessments and potential paths forward are described below.

- Because some surfactants, particularly POEA are more toxic than glyphosate to aquatic organisms, glyphosate formulations containing POEA and other surfactants need to be identified and considered in the risk assessment. Particular attention will be given to any glyphosate formulations containing POEA that are registered for direct applications to aquatic environments.

- A spray buffer zone analysis is needed to determine potential exposure reductions to non-target aquatic and terrestrial plants.

B. Endangered Species

Consistent with the Agency's responsibility under the Endangered Species Act (ESA), EPA will evaluate risks to Federally-listed threatened and/or endangered (listed) species from registered uses of glyphosate. This assessment will be conducted in accordance with the Overview Document (USEPA, 2004), provisions of the ESA, and the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998).

The assessment of effects associated with registrations of glyphosate is based on an action area. The action area is considered to be the area directly or indirectly affected by the federal action, as indicated by the exceedance of Agency Levels of Concern (LOCs) used to evaluate direct or indirect effects. The Agency's approach to defining the action area under the provisions of the Overview Document (USEPA, 2004) considers the results of the risk assessment process to establish boundaries for that action area with the understanding that exposures below the Agency's defined LOCs constitute a no-effect threshold. For the purposes of this assessment, attention will be focused on the footprint of the action (*i.e.*, the area where glyphosate application occurs), plus all areas where offsite transport (*i.e.*, spray drift and runoff) may result in potential exposure that exceeds the Agency's LOCs. Specific measures of ecological effect that define the action area for listed species include any direct and indirect effects and/or potential modification of its critical habitat, including reduction in survival, growth, and reproduction as well as the full suite of sublethal effects available in the effects literature. Therefore, the action area extends to a point where environmental exposures are below any measured lethal or sublethal effect threshold for any biological entity at the whole organism, organ, tissue, and cellular level of organization. In situations where it is not possible to determine the threshold for an observed effect, the action area is not spatially limited and is assumed to be the entire United States.

C. Drinking Water Assessment

The most recent drinking water assessment is based on the GENEEC model and a direct application of glyphosate to a farm pond. Different exposure models have replaced GENEEC and are now used for drinking water assessments, so an updated drinking water assessment will be needed for a human health dietary risk assessment. The Tier 1 FIRST model and direct glyphosate application in the index reservoir will be used. In addition, an updated drinking water assessment will include any monitoring data that may be available.

D. Clean Water Act

Glyphosate is not identified as a cause of impairment for any water bodies listed as impaired under section 303(d) of the Clean Water Act, based on information provided at http://iaspub.epa.gov/tmdl_waters10/attains_nation_cy.cause_detail_303d?p_cause_group_id=885. In addition, no Total Maximum Daily Loads (TMDL) have been developed for glyphosate, based on information provided at http://iaspub.epa.gov/tmdl_waters10/attains_nation.tmdl_pollutant_detail?p_pollutant_group_id=885&p_pollutant_group_name=PESTICIDES. More information on impaired water bodies and TMDLs can be found at http://www.epa.gov/owow/tmdl/.

The Agency invites submission of water quality data for this pesticide. To the extent possible, data should conform to the quality standards in Appendix A of the *OPP Standard Operating Procedure: Inclusion of Impaired Water Body and Other Water Quality Data in OPP's Registration Review Risk Assessment and Management Process* (see: http://www.epa.gov/oppfead1/cb/ppdc/2006/november06/session1-sop.pdf), in order to ensure they can be used quantitatively or qualitatively in pesticide risk assessments.

E. Anticipated Data Needs

Aquatic Toxicity

In some end use products, the active ingredient is formulated with a surfactant to improve efficacy. Studies show that these formulated products can be more toxic than the active ingredient alone, especially to aquatic organisms. Because of the increased toxicity of formulated products, they will be considered in the ecological risk assessment to be conducted for registration review.

One class of surfactants used in glyphosate formulations are the polyethoxylated tallow amines (POEA). There are many ecological effects studies conducted with POEA formulations and some of these studies show increased sensitivity of aquatic organisms when exposed to POEA. Only a few ecological effects studies have been conducted with formulations containing surfactants other than POEA. The toxicities of some of these formulations appear to be either similar to or less toxic than the technical material. However, there are some non-POEA formulations that appear to be quite a bit more toxic than the technical material. For most formulations, we have no data.

Because the available data indicate the possibility that some formulations, even those not containing POEA can be considerably more toxic to aquatic organisms than the technical material alone, there is considerable uncertainty about the risk to aquatic organisms. There are many formulated products for glyphosate and the surfactants used in these products that must first be identified. Without toxicity data on specific formulations, the Agency is considering two possible approaches to addressing the toxicity of formulated products that are registered for direct application to water. The first approach is to consider structure activity relationships for the surfactants. The Agency would use the data that it does have (e.g. POEA) to predict the toxicity of surfactants with similar structure. A second approach is to request toxicity testing for a subset of the surfactants.

The Agency asks for comment on the proposed approaches and is open to other suggestions for addressing these uncertainties.

Guideline Number: 850.2100 **Study Title: Avian Acute Oral Toxicity Test**
Rationale for Requiring the Data
Acceptable acute avian oral toxicity data were not submitted for a passerine species exposed to glyphosate, which is now required under the 40 CFR Part 158 (CFR 40 2008) data requirements for conventional pesticides. The new Part 158 data requirements specify that acute avian oral toxicity data be submitted for either one waterfowl or one upland game species and one passerine species. The available acute oral toxicity data for bobwhite quails (upland game species) indicate that glyphosate is practically nontoxic to birds on an acute basis (a quantitative risk assessment cannot be done because there is no definitive endpoint). No data is available for a waterfowl species (e.g. mallard duck). Because passerine species have higher metabolic rates due to their smaller sizes than either waterfowl or upland game bird species and because they may utilize different metabolic pathways, they may be more or less sensitive to glyphosate. In order to properly characterize risk to passerines, an avian oral toxicity test is required for passerine birds. A passerine study protocol must be submitted for review by the Agency prior to initiation of the study.
Practical Utility of the Data
How will the data be used? Acute avian oral toxicity data for passerine species will be used to refine the screening-level assessment by determining whether there are differences in avian species sensitivity to glyphosate between passerine and upland game species. Based on the currently submitted acute oral bobwhite quail data, glyphosate is practically nontoxic to birds on an acute basis. Furthermore, because there is no definitive toxicity endpoint for upland game species, the method of adjusting the LD_{50} value based on body weight alone cannot be done. Therefore, risk to passerine species may be underestimated by applying the qualitative risk conclusions from the bobwhite quail. **How could the data impact the Agency's future decision-making?** If future risk assessments, including listed species assessments, are performed without these data, the Agency would have to assume that glyphosate "may affect" listed birds directly (and listed species from other taxa indirectly), and use of glyphosate and its formulated products may need to be restricted in areas where listed species could be exposed. The lack of these data will limit the flexibility the Agency and registrants have in coming into compliance with the Endangered Species Act and could result in restrictions for glyphosate use that are unnecessarily severe.

Guideline Number: 850.1025, 850.1035, 850.1045, 850.1055, 850.1075 **Study Title: Acute toxicity estuarine/marine organisms**
Rationale for Requiring the Data
The Part 158 data requirements specify that one estuarine/marine mollusk, one estuarine/marine invertebrate, and one estuarine/marine fish species test with a typical end use product be submitted when an ingredient in the end-use formulation other than the active ingredient is expected to enhance the toxicity of the active ingredient or to cause toxicity to aquatic organisms. At least one surfactant, MON 0818 (polyoxy ethylene fatty amine), used in some glyphosate formulations has been shown to be toxic to aquatic organisms. For freshwater organisms, formulations containing POEA show greatly increased toxicity over formulations without POEA and technical grade glyphosate. Although toxicity data on formulations that do not contain POEA (e.g. aquatic use formulations) have been submitted to the Agency for estuarine/marine organisms, based on the toxicity of POEA to freshwater organisms, it is assumed that toxicity is also increased to marine/estuarine organisms. Formulations with POEA appear to be registered for terrestrial uses only, however, terrestrial formulations used in coastal areas are expected to potentially contaminate marine ecosystems and estuaries through spray drift. In order to properly characterize risk to marine/estuarine organisms, acute toxicity tests are required for a formulation containing the POEA surfactant.
Practical Utility of the Data
How will the data be used? Acute estuarine/marine organism tests with formulations containing POEA will be used to refine the screening-level assessment by determining the acute toxicity of glyphosate formulations containing POEA to estuarine/marine species and finding whether or not these species are more sensitive to POEA-containing products. Using the currently available acute estuarine/marine organism data for typical end use products not containing POEA could potentially underestimate risk to marine/estuarine organisms. **How could the data impact the Agency's future decision-making?** If future risk assessments, including listed species assessments, are performed without these data, the Agency would have to assume that glyphosate "may affect" listed marine/estuarine organisms directly (and listed species from other taxa indirectly), and use of glyphosate and its formulated products may need to be restricted in areas where listed species could be exposed. The lack of these data will limit the flexibility the Agency and registrants have in coming into compliance with the Endangered Species Act and could result in restrictions for glyphosate use that are unnecessarily severe.

Other Information Needs

There is specific information that will assist the Agency in refining the ecological risk assessment, including any species-specific effects determinations. The Agency is very much interested in obtaining the following information:

1. confirmation on the following label information
    a. sites of application
    b. formulations
    c. application methods and equipment
    d. maximum application rates

    e. frequency of application, application intervals, and maximum number of applications per season
    f. geographic limitations on use
2. use or potential use distribution (e.g., acreage and geographical distribution of relevant crops)
3. use history
4. median and 90th percentile reported use rates (lbs ai/acre) from usage data – national, state, and county
5. application timing (date of first application and application intervals) by crop – national, state, and county
6. sub-county crop location data
7. usage/use information for non-agricultural uses (e.g., forestry, residential, rights-of-way)
8. directly acquired county-level usage data (not derived from state level data)
    a. maximum reported use rate (lbs ai/acre) from usage data – county
    b. percent crop treated – county
    c. median and 90th percentile number of applications – county
    d. total pounds per year – county
    e. the year the pesticide was last used in the county/sub-county area
    f. the years in which the pesticide was applied in the county/sub-county area
9. typical interval (days)
10. state or local use restrictions
11. ecological incidents (non-target plant damage and avian, fish, reptilian, amphibian and mammalian mortalities) not already reported to the Agency
12. monitoring data
13. comment on proposed approaches to addressing the toxicity of formulated products that are registered for direct application to water

The analysis plan will be revisited and may be revised depending upon the data available in the open literature and the information submitted by the public in response to the opening of the Registration Review docket.

VIII. References

Baker, N.T., Stone, W.W., Wilson, J.T., and Meyer, M.T., 2006. Occurrence and Transport of Agricultural Chemicals in Leary Weber Ditch Basin, Hancock County, Indiana, 2003-2004. 2005 National Water Quality Assessment Program. U.S. Department of the Interior, U.S. Geological Survey, Scientific Investigations Report, 2006-5251. Battaglin, W.A., Kolpin, D.W., Scribner, E.A, Kuivila, K,M., and sandstorm, M.W. 2005. Journal of the American Water Resources Association (JAWRA), April, pp. 323-332

Kolpin, D.W, Thurman, M.E. Lee, E.A., T. Meyer, M.T, Furlong, E.T., and Glassmeyer, S.T., 2006. Urban contributions of glyphosate and its degradate AMPA to streams in the United States. Science of the Total Environment; Volume 354, Issues 2-3, Pages 191-197

Lee, E.A., Strahan, A.P., and Thurman, E.M., 2001. Methods of Analysis by the U.S. geological Survey Organic Geochemistry Research Group- Determination of Glyphosate, Aminomethylphosphonic Acid, and Glufosinate in Water Using Online Solid-Phase Extraction and High Performance Liquid Chromatography/Mass Spectrometry. U.S. Geological Survey Open File Report 01-454. U.S. Geological Survey Open File Report 03-217

Quaghebeur, D., De Smet B., De Wulf, E., Steurbaut, W., 2004. Pesticides in rainwater in Flanders, Belgium: results from the pesticide monitoring program 1997-2001. Journal of Environmental Monitoring 6: 182-190

Scribner, E.A., Battaglin, W.A., Dietze, J.E., and Thurman, E.M., 2003. Reconnaissance Data for Glyphosate, Other Selected Herbicides, their Degradation Products, and Antibiotics in 51 Streams in Nine Midwestern States, 2002. U.S. Geological Survey Open File Report 03-217

U.S. Department of Agriculture (USDA), 2003. Glyphosate – Human Health and Ecological Risk Assessment Final Report. Prepared for the United States Department of Agriculture Forest Service, Forest Health Protection. Prepared by Syracuse Environmental Research Associates, Inc. Document Number SERA TR 02-43-09-04a. March 3, 2003.

U.S. Environmental Protection Agency (USEPA), 2004. Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs. Office of Prevention, Pesticides, and Toxic Substances. Office of Pesticide Programs. Washington, D.C. January 23, 2004

U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), 1998. Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities Under Section 7 of the Endangered Species Act. Final Draft. March 1998

APPENDIX A

Maximum Glyphosate Use Rate and Management Practices
(Generalized Screening Level Portrayal of Current Label Uses. Source: BEAD LUIS report May 6, 2008)

Group name	Uses represented[1]	Max. Rate per App. (lb a.i./A) [2, 3, 4]	Seasonal Max. Dose/Year (lb) [2, 4]	Application Method [5]
Food/Feed Uses				
Acerola (West Indies Cherry)		3.75	6.05	Ground
Agricultural fallow/idleland		3.84	6	Aerial, Ground
Aloe Vera		3.67	6	Ground
Artichoke		3.67	6	Ground
Asparagus		3.84	6.15	Aerial, Ground
Atemoya		3.75	6.05	Ground
Avocado		3.84	6.05	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Bamboo shoots		3.67	6	Ground
Banana		3.84	7.93	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Berries and small fruits	Blackberry, Blueberry, Boysenberry, Cranberry, Currant, Dewberry, Elderberry, Gooseberry, **Grapes** [a], Huckleberry, Kiwi fruit [a], Loganberry, Olallie berries, Raspberry (black, red), Small fruits (unspecified) [a], Strawberry [a]	2.2 to 3.84	6 to 8.15	Aerial, Ground
	Cranberry, Grapes, Small fruits (unspecified)	14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
	Caneberry, Grapes	8.847 (0.061 lb / 300 ft^2) [d]	NS	
Brassica (Cole) leafy vegetables	**Broccoli, Brussels sprouts, Cabbage, Cabbage (Chinese),**	3.67 to 3.84	6 to 6.15	Aerial, Ground

Group name	**Uses represented**[1]	**Max. Rate per App. (lb a.i./A)** [2, 3, 4]	**Seasonal Max. Dose/Year (lb)** [2, 4]	**Application Method** [5]
	Cauliflower, Collards, Kale, Kohlrabi, unspecified [a]			
Breadfruit (Breadnut)		3.75	6.05	Ground
Bulb vegetables	**Garlic, Leek, Onion**	3.84	6.15	Aerial, Ground
Canistel		3.75	6.05	Ground
Canola/Rape		3.84	6.15	Aerial, Ground
Carambola (Jalea)		3.75	6.05	Ground
Cereal grains	**Barley**, **Corn** (field, popcorn, sweet, **unspecified**), **Millet (proso)**, **Oats**, **Rice**, **Rye**, Sorghum, **Triticale**, unspecified[a], **Wheat**	3.67 to 3.84	6 to 6.15	Aerial, Ground
Cherimoya		3.75	6.05	Ground
Cherry		3.84	8.15	Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Citrus	Calamondin, **Citrus citron, Citrus** [a], Grapefruit, Kumquat, Lemon, Lime, Orange, Pummelo (Shaddock), Tangelo, Tangerines	3.75 to 3.84	6.15 to 7.92	Aerial, Ground
	Citrus citron, Grapefruit, Kumquat, Lemon, Lime, Orange, Pummelo (Shaddock), Tangelo, Tangerines	14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Cocoa		3.75	6.05	Ground
Coconut		3.75	7.93	Ground
Coffee		3.84	7.93	Aerial, Ground
Cotton (unspecified)		3.84	6.15	Aerial, Ground
Crops grown		3.67	6	Ground

Group name	Uses represented[1]	Max. Rate per App. (lb a.i./A) [2, 3, 4]	Seasonal Max. Dose/Year (lb) [2, 4]	Application Method [5]
for oil (unspecified)				
Cucurbit vegetables	**Cucumber**, **Gourds**, **Muskmelon (cantaloupe, casaba, crenshaw, honeydew, persian, mango melon, unspecified)**, **Pumpkin**, Squash (summer, winter – hubbard), **Squash (unspecified)**, unspecified [a], **Watermelon**	2.2 to 3.84	6 to 6.15	Aerial, Ground
Date		3.84	6.05	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Fig		3.84	6.05	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Forage, fodder, and straw of cereal grains	**Corn**, Sorghum [b]	1.13 to 3.67	6	Aerial, Ground
Fruiting vegetables (except cucurbits)	**Eggplant, Pepper, Tomatillo, Tomato**	3.84	6.15	Aerial, Ground
Fruiting vegetables (unspecified)		3.67	6	Ground
Fruits (unspecified)		3.75	6.05	Ground
Grass forage, fodder, and hay	Bermuda grass [a, b] **Grass grown for seed**, **Pasture**, Rangeland [a], unspecified	0.387 to 3.84	2.22 to 6.15	Aerial, Ground
Guava		5.21	8.34	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	

Group name	Uses represented[1]	Max. Rate per App. (lb a.i./A) [2, 3, 4]	Seasonal Max. Dose/Year (lb) [2, 4]	Application Method [5]
Herbs and spices	**Mustard**, unspecified [a]	3.67 to 3.84	6 to 6.15	Aerial, Ground
	unspecified	8.847 (0.061 lb / 300 ft^2) [d]	NS	
Hops		3.67	7.93	Ground
Jaboticaba		3.75	6.05	Ground
Jackfruit		3.75	6.05	Ground
Leafy vegetables (except *Brassica*)	**Celery, Endive (Escarole), Lettuce, Parsley, Rhubarb, Spinach, Swiss chard**	3.84	6.15	Aerial, Ground
Leafy vegetables (unspecified)		3.67	6	Ground
Leaves of root and tuber vegetables	**Sugar beets (includes tops)**	3.84	6.15	Aerial, Ground
Legume vegetables	**Beans**, Lentils, **Peas (unspecified), Soybeans (unspecified)**, unspecified	2.2 to 4.48	6 to 6.15	Aerial, Ground
Litchi nut		3.75	6.05	Ground
Longan		3.75	6.05	Ground
Mango		3.75	6.05	Ground
Marmaladebox (Genipapo)		3.75	6.05	Ground
Mint/ Peppermint/ Spearmint		3.67	6	Ground
Non-grass forage, fodder, straw, and hay	**Alfalfa, Clover**, unspecified	3.75 to 3.84	6.05 to 6.15	Aerial, Ground
Okra		3.67	6	Aerial, Ground
Olive		3.84	8.15	Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Orchards (unspecified)		1.51	6.05	Ground
Palm		3.67	7.93	Ground
Papaya		3.84	7.93	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	

Group name	Uses represented[1]	Max. Rate per App. (lb a.i./A) [2, 3, 4]	Seasonal Max. Dose/Year (lb) [2, 4]	Application Method [5]
Passion Fruit (Granadilla)		3.84	7.93	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Peanuts		3.84	6.15	Aerial, Ground
Persimmon		3.84	6.05	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Pineapple		3.84	6	Aerial, Ground
Pistachio		3.84	8.15	Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Plantain		3.84	7.93	Aerial, Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Pome fruits	**Apple**, Mayhaw (hawthorn), **Pear**, unspecified	3.75 to 3.84	6.05 to 8.15	Ground
	Apple, Pear, Loquat, Quince	14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Pomegranate		3.75	6.05	Ground
		14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
Pricklypear cactus pads		3.67	7.93	Ground
Sapodilla		3.75	6.05	Ground
Root and tuber vegetables	Artichoke - Jerusalem, Beets, Chicory, Ginseng [a], Horseradish, **Potato (White/Irish)**, Radish, Rutabaga, Sugar beet, Turnip (root), unspecified [a]	2.2 to 3.84	6 to 6.15	Aerial, Ground
Sapota (white)		3.75	6.05	Ground
Small grains (unspecified)		3.75	6.05	Aerial, Ground
Soursop		3.75	6.05	Ground
Stone fruits	**Apricot**, **Nectarine**, **Peach**, **Plum**, **Prune**, unspecified	3.75 to 3.84	7.93 to 8.15	Ground
	Apricot, Nectarine,	14.93 (0.514	NS	

Group name	**Uses represented**[1]	**Max. Rate per App. (lb a.i./A)** [2, 3, 4]	**Seasonal Max. Dose/Year (lb)** [2, 4]	**Application Method** [5]
	Peach, Plum, Prune	lb/ 1500 ft^2) [c]		
Subtropical/ Tropical fruit		3.67	7.93	Ground
Sugar apple (Custard apple)		3.75	6.05	Ground
Sugarcane		3.75	6.05	Aerial, Ground
Sunflower		3.67	6.05	Ground
Tamarind		3.75	6.05	Ground
Tea		3.75	6.05	Ground
Tree nuts	**Almond**, **Beech nut**, **Brazil nut**, **Butternut**, **Cashew**, **Chestnut**, **Filbert (hazelnut)**, **Hickory nut**, **Macadamia nut (bush nut)**, **Pecan**, unspecified, **Walnut (English, black)**	3.75 to 3.84	7.93 to 8.15	Ground
	Almond, Beech nut, Brazil nut, Butternut, Cashew, Chestnut, Filbert (hazelnut), Hickory nut, Macadamia nut (bush nut), Pecan, Walnut (English, black)	14.93 (0.514 lb/ 1500 ft^2) [c]	NS	
	unspecified	8.847 (0.061 lb / 300 ft^2) [d]	NS	
Vegetables (unspecified)		3.75	6.05	Ground
		8.847 (0.061 lb / 300 ft^2) [d]	NS	
Watercress		2.2	6	Aerial, Ground
Non-Food/Non-Feed Uses				
Aquatic uses	Drainage Systems	0.154	NS	Ground
Forestry	Forest Trees (all or unspecified)	7.35	7.93	Aerial, Ground
Greenhouse	**Empty**, **Nursery**, **Ornamental Non-flowering Plants**, **Ornamental and/or**	3.67	7.93	Ground

Group name	Uses represented[1]	Max. Rate per App. (lb a.i./A) [2,3,4]	Seasonal Max. Dose/Year (lb) [2,4]	Application Method [5]
	Shade Trees, Ornamental Woody Shrubs and Vines			
Non-crop uses	Commercial storage/ Warehouse premises [b], Commercial/ Institutional/Industrial premises/Equipment (outdoor) [b], Household/Domestic dwellings outdoor premises [b], **Industrial areas (outdoor)**, Nonagricultural outdoor buildings/structures [b], Paths/Patios [b], Paved areas (Private roads/sidewalks) [b]	3.6 to 3.84	7.92	Ground
	Household/Domestic dwellings outdoor premises, Nonagricultural outdoor buildings/structures, Paths/Patios	0.106 to 0.342 lb / 1000 ft^2 [e]	NS	
Non-food crops	Agricultural fallow/ idleland, Agricultural rights-of-way/ fencerows/ hedgerows [b], **Agricultural uncultivated areas**, Christmas tree plantations, Golf course turf [b], Non-agricultural rights-of-way/ fencerows/ hedgerows, Non-agricultural uncultivated areas,	3.6 to 7.93	7.92 to 11.05	Ground Aerial, Ground -- Agricultural fallow/ idleland, Agricultural rights-of-way/ fencerows/ hedgerows, Non-agricultural rights-of-way/ fencerows/

Group name	Uses represented[1]	Max. Rate per App. (lb a.i./A) [2, 3, 4]	Seasonal Max. Dose/Year (lb) [2, 4]	Application Method [5]
	Nursery, Ornamental herbaceous plants, Ornamental lawns and turf, Ornamental Non-flowering Plants, Ornamental and/or shade trees, Ornamental sod farm (turf), Ornamental woody shrubs and vines, Recreational areas			hedgerows, Non-agricultural uncultivated areas, Ornamental lawns and turf
	Fencerows/ Hedgerows, Mulch, Non-agricultural uncultivated areas, Ornamental herbaceous plants, Ornamental lawns and turf , Ornamental and/or shade trees, Ornamental woody shrubs and vines	0.34 to 0.436 lb / 1000 ft^2 [e]	NS	
Residential uses	**Ornamental herbaceous plants**, Ornamental lawns and turf [b], Ornamental and/or shade trees [b], Ornamental woody shrubs and vines [b], Rights-of-way/ Fencerows/Hedgerows[b]	3.6 to 3.84	7.93	Ground
	Fruits (unspecified), Mulch, Ornamental and/or shade trees, Ornamental herbaceous plants, Ornamental lawns and turf, Ornamental non-flowering plants, Ornamental woody	0.201 to 0.436 lb / 1000 ft^2 [e]	NS	

Group name	Uses represented[1]	Max. Rate per App. (lb a.i./A) [2, 3, 4]	Seasonal Max. Dose/Year (lb) [2, 4]	Application Method [5]
	shrubs and vines, Residential lawns, Rights-of-way/ Fencerows/Hedgerows			

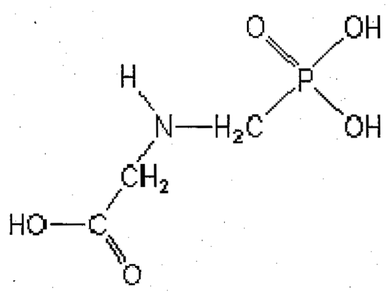
[1] When possible, crops/uses were grouped. Food/Feed use groups were based on 40 CFR (7-1-08 edition) crop group tables. Non-Food/Non-Feed use groups were generally based on use groups reported in LUIS reports. For grouped crops/uses, **bold** text indicates the crop(s)/use(s) with the highest seasonal maximum dose/year within each group.
[2] In cases of grouped crops/uses, the range represents the maximum rate per application and seasonal maximum dose/year of each crop/use within the group.
[3] Application rate in terms of lb a.i./A unless otherwise indicated (e.g. lb a.i./1500 ft^2).
[4] Seasonal maximum dose/year and maximum rate per application may not be from the same labeled use.
[5] Application methods reported for any labeled application rates (maximum rate per application and/or seasonal maximum dose/year) for that crop/use. The term ground includes any of the ground methods previously defined as ground. In some cases when both aerial and ground application methods are reported for a crop/use, both methods may not be used at the maximum reported application rates (single application and/or seasonal application).

[a] Ground application only
[b] Seasonal rate not stated
[c] Maximum application rate treated by one package of product is 0.514 lb a.i. / 1500 ft^2 or 14.93 lb a.i. / A (data source: BEAD LUIS report May 6, 2008). Seasonal dose is not stated on the product label. Application method is sprayer or spot treatment.
[d] Label indicates product for home and garden use with spot or spray treatment of 300 ft^2. Seasonal dose is not stated on the product label. Maximum single application rate is 8.847 lb a.i. / A (data source: BEAD LUIS report May 6, 2008). We back calculated rate of application as 0.0609 lb a.i. / 300 ft^2 using the formula: lb a.i. / A = (lb a.i. / A) * (1 A / 43560 ft^2).
[e] In certain cases the labeled application rate is for a treatment coverage area less than one acre. It was then assumed that intended application of the product is for an area less than one acre.

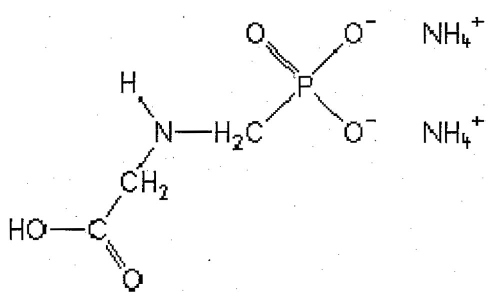
APPENDIX B

Structures of Glyphosate and AMPA

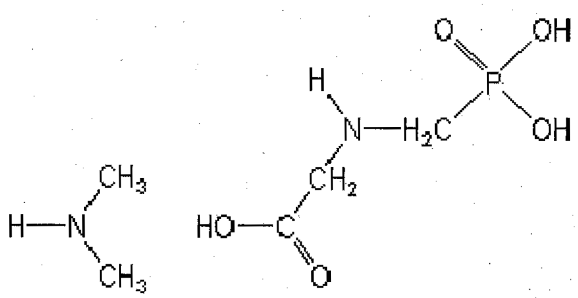
Glyphosate Acid



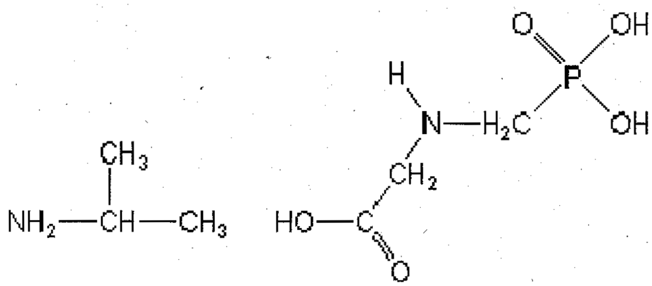
Diammonium salt glyphosate



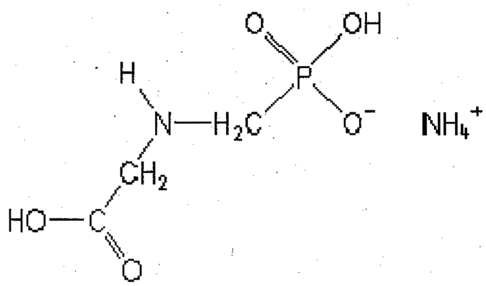
N-methylmethanamine glyphosate



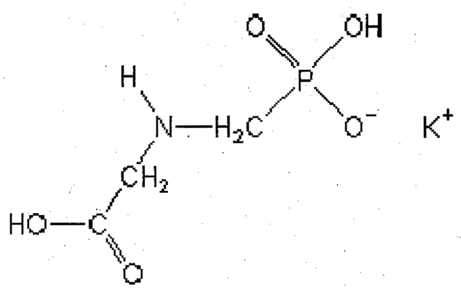
Isopropyl ammonium glyphosate



Monoammonium salt glyphosate



Potassium salt glyphosate



AMPA-Degradation Product